Evaluating stress as a challenge is associated with superior attentional control and motor skill performance: Testing the predictions of the biopsychosocial model of challenge and threat

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Abstract

The biopsychosocial model of challenge and threat (Blascovich, 2008) suggests that individuals who evaluate a performance situation as a challenge will perform better than those who evaluate it as a threat. However, limited research has examined (1) the influence of challenge and threat evaluations on learned motor performance under pressure and (2) the attentional processes by which this effect occurs. In the present study 52 novices performed a motor task (laparoscopic surgery), for which optimal visual attentional control has been established. Participants performed a Baseline trial (when the task was novel) and were then trained to proficiency before performing under pressurized conditions designed to increase anxiety (Pressure). At Baseline, regression analyses were performed to examine the relationship between challenge/threat evaluations and the outcome variables (performance, cardiovascular response and visual attention). At Pressure, hierarchical regression analyses (controlling for the degree of learning) were performed to examine the relationship between challenge/threat evaluations and the outcome variables. At both Baseline and Pressure tests evaluating the task as more of a challenge was associated with more effective attentional control and superior performance. In the Baseline test, evaluating the task as more of a challenge was associated with differential cardiovascular responses. While there is some support for an attentional explanation of differential performance effects, additional analyses did not reveal mediators of the relationship between challenge/threat evaluations and motor performance. The findings have implications for the training and performance of motor skills in pressurized environments (e.g., surgery, sport, aviation).

Key words: attentional control theory; biopsychosocial model; gaze control; anxiety; surgery

Evaluating stress as a challenge is associated with superior attentional control and motor skill performance: Testing the predictions of the biopsychosocial model of challenge and threat

The biopsychosocial model of challenge and threat (Blascovich, 2008) is a theoretical framework that explains variations in performance in situations where individuals are motivated to attain self-relevant goals (motivated performance situations; e.g., exam taking, speech giving, sporting competition). When individuals are engaged in such tasks, they evaluate the demands of the task and whether they possess the necessary resources to cope effectively with these demands (Seery, 2011). Those individuals who evaluate that they have sufficient resources to cope with the demands of a task (a challenge evaluation) tend to perform better than individuals who evaluate that they do not possess the required resources to meet the task demands (a threat evaluation; Seery, 2011). The current study adopts a novel training design to further our understanding of how the biopsychosocial model of challenge and threat may explain individual performance variability in applied environments where skills need to be performed under pressure (e.g., military, surgery, sport, aviation).

According to the biopsychosocial model of challenge and threat, an individual's evaluation of a stressful situation (evaluating demands and resources) can be assessed via self-report measures, (e.g., the cognitive appraisal ratio; Tomaka, Blascovich, Kelsey, & Leitten, 1993) and by distinctive patterns of neuroendocrine and cardiovascular responses (Blascovich, 2008; Seery, 2011). Specifically, whilst both evaluations are characterized by an increase in heart rate and a reduction in cardiac pre-ejection period (the time interval from the electrical stimulation of the ventricles to the opening of the aortic valve), a challenge evaluation is marked by relatively higher cardiac output and lower total peripheral resistance compared to a threat evaluation (Seery, 2011).

Empirical and predictive studies in psychology have shown that a challenge evaluation is typically associated with superior performance compared to a threat evaluation (e.g., Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004; Mendes, Blascovich, Hunter, Lickel, & Jost, 2007; Moore, Vine, Wilson, & Freeman, 2012; Seery, Weisbuch, Hetenyi, & Blascovich, 2010; Turner, Jones, Sheffield, & Cross, 2012). The vast majority of studies have investigated the distal effects of challenge and threat evaluations on performance in applied settings (e.g., academic - Seery et al., 2010; sport - Blascovich et al., 2004) or their immediate effects on cognitive task performance (e.g., word-finding - Mendes et al., 2007; Stroop test - Turner et al., 2012), with very few examining acute effects on perceptual-motor task performance. In one such study, Moore et al. (2012) manipulated the instructions provided to novice golfers prior to a golf putting test to create two experimental groups (challenge vs. threat). As predicted by the biopsychosocial model of challenge and threat, they found differential demand/resource evaluations and cardiovascular responses between the groups. Additionally, the challenge group putted more accurately, and displayed more efficient putting kinematics and forearm muscle activity than their threat group counterparts (Moore et al., 2012).

A limitation of research testing the biopsychosocial model of challenge and threat is that few studies have examined the possible mechanisms through which challenge and threat evaluations might influence performance (see Moore et al., 2012; O'Connor, Arnold, & Maurizio, 2010 for notable exceptions). Several underlying mechanisms have been proposed, including those related to attentional processes (e.g., Blascovich et al., 2004; Jones, Meijen, McCarthy, & Sheffield, 2009; Skinner & Brewer, 2004). These authors have postulated that the focus of attention may be on task-relevant cues following a challenge evaluation, whereas attention may be directed to task-irrelevant cues following a threat evaluation. As a threat evaluation is linked to increased anxiety (Jones et al., 2009; Moore et al., 2012; Quested, Bosch, Burns, Cumming, Ntoumanis, & Duda, 2011), parallels can be drawn to recent research which has identified that increased anxiety causes disruptions to attentional control and a breakdown in perceptual motor skill performance (see Wilson, 2012 for a review).

Much of this research has discussed the anxiety-induced impairment of optimal attentional control in relation to the predictions of attentional control theory (Eysenck et al., 2007). Specifically, attentional control theory suggests that anxiety causes an increase in the sensitivity and influence of the stimulus-driven (bottom-up) attentional system at the expense of the goal-directed (top-down) attentional system. According to attentional control theory, anxiety reduces attentional control making it difficult for the goal-directed attentional system to override the stimulus-driven attentional system (Eysenck et al., 2007). This impairment in attentional control has been shown to be reflected in disruptions in gaze control in perceptual motor tasks, characterized by an increased focus on areas that are of little or no importance to the task (see Wilson, 2012; Nieuwenhuys & Oudejans, 2012 for reviews).

Thus, in order to probe the processes by which challenge and threat evaluations influence performance, a testable hypothesis is that challenge (as opposed to threat evaluations) should be associated with more effective attentional control. Indeed, Moore et al. (2012) provided evidence for this attentional explanation by examining differences in the quiet eye fixation (Vickers, 1996) – an objective measure of goal directed visual attentional control that has been shown to underpin successful skill execution in sporting tasks (see Mann, Williams, Ward, & Janelle, 2007; Vine, Moore, & Wilson, 2012a for reviews). The challenge group not only performed better than their threat group counterparts, but also maintained goal directed attentional control (longer quiet eye fixations) prior to initiating and throughout the putting stroke (Moore et al., 2012).

While the quiet eye is a relevant index of optimal visual attentional control in golf putting (Moore et al., 2012), research in a variety of performance settings suggests that each visually-guided motor task has a specific goal-directed attentional strategy that underpins optimal performance (e.g., Land, 2009). Laparoscopic (minimally invasive) surgery is a complex visuomotor task, with increased difficulty compared to traditional (open) surgical procedures. Learning laparoscopic skills therefore involves the adaptation of previously acquired basic sensorimotor rules for manual reaching and grasping (Sailer, Flanagan, & Johansson, 2005). Recent research in laparoscopic tasks has identified that experts primarily fixate the target to be grasped and seldom need to check the location of the tools (a *target locking* strategy), whereas novices, still developing the mapping rules, switch between tracking the tool as it moves towards the target and fixating the target itself (a *switching* strategy; Wilson, Vine, Bright, Masters, Defriend, & McGrath, 2011). The expert-like target locking strategy has been shown to be trainable, leading to improved learning, and more robust performance in pressurized conditions (Vine, Masters, McGrath, Bright, & Wilson, 2012b; Wilson et al., 2011). Given that a challenge state has previously been associated with more effective visual attentional control (Moore et al., 2012), evaluating a laparoscopic surgery task as a challenge may encourage a gaze strategy consisting of relatively greater target locking, as supported by the predictions of attentional control theory. Such superior visual attentional control might ultimately benefit task performance due to more effective sensorimotor mapping (see Sailer et al., 2005).

The aims of the present study were two fold. First, the study aimed to examine the effect of challenge and threat evaluations upon attentional control and performance in a novel, un-learned motor task (laparoscopic surgery). This enabled us to test the generalizability of Moore et al.'s (2012) findings in golf putting. Second, the study aimed to investigate the effect of challenge and threat evaluations upon attentional control and performance when the task was learned and performed under pressurized (ego threatening) circumstances. We hypothesized that task evaluations would significantly predict performance in both the Baseline (before training) and Pressure tests (following training). We also hypothesized that in both Baseline and Pressure tests, pre-task evaluations would significantly predict visual attentional control. Specifically, more favourable evaluations would be associated with greater target locking.

Method

Participants

A total of 52 participants (27 women, 25 male) with a mean age of 20.50 years (*SD* = 1.85) volunteered to take part in the study. All participants were right-hand dominant and were novice medics (final-year medical students) who had received no prior laparoscopic training (as Wilson et al., 2011). All reported being non-smokers, free of illness or infection, and had normal or corrected vision, no known family history of cardiovascular or respiratory disease; had not performed vigorous exercise or ingested alcohol for 24 hours prior to testing; and had not consumed food and/or caffeine for 1 hour prior to testing. Participants were tested individually. The protocol was approved by the local ethics committee and written informed consent was obtained from each participant.

Self-Report Measures

Cognitive anxiety. Cognitive state anxiety was measured using the cognitive subscale from the Mental Readiness Form-3 (MRF-3; Krane, 1994). Participants were asked to report how they felt about the upcoming task on an 11 point Likert scale anchored between *not worried (= 1) and worried (= 11)*. The MRF-3 is a shorter and more expedient alternative to the Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Burton, Vealey, Bump, & Smith, 1990) and Krane's (1994) validation work revealed correlations between the MRF-3 and the CSAI-2 subscales of .76 for cognitive anxiety. This self-report measure has been used in previous research examining the impact of cognitive anxiety on motor task performance (e.g., Vine, Moore, & Wilson, 2011). Cronbach's alpha was .78 for both tests at which anxiety was assessed (i.e., Retention and Pressure).

Demand/resource evaluations. Demand evaluations were assessed by asking "How demanding do you expect the laparoscopic surgery task to be?" whilst resource evaluations were assessed by asking "How able are you to cope with the demands of the laparoscopic surgery task?". These two items were rated using a 6-point Likert scale anchored between *not at all (= 1)* and *extremely (= 6)*. These scales have been widely used in the challenge and threat literature (e.g., Feinberg & Aiello, 2010; Moore et al., 2012). Previous studies, interested in comparing distinct challenge and threat groups, have typically calculated a ratio score by dividing demands by resources (e.g. Feinberg & Aiello, 2010; Moore et al., 2012; Tomaka et al. 1993). However, such a ratio is highly non-linear[1], and as such is not appropriate for the regression-based analyses performed on the data in the current study (see Methods section). Instead a Demand Resource Evaluation Score (DRES) was calculated by subtracting demands from resources (range: -5 to +5), with a more positive score reflecting a challenge evaluation (see Tomaka et al., 1993).

Cardiovascular Measures

A non-invasive impedance cardiograph device (Physioflow, PF05L1, Manatec Biomedical, Paris, France) was used to estimate heart rate and cardiac output. The Physioflow measures impedance changes in response to a high frequency (75 kHz) and low-amperage (3.8 mA) electrical current emitted via six spot electrodes (Blue Sensor R, Ambu, Ballerup, Denmark) positioned on the chest of the participant (for a detailed description of the electrode configuration see Moore et al., 2012). After entering the participant's anthropometric details (height, weight, and gender), the Physioflow was calibrated over 30 heart cycles while participants sat resting in an upright position. Three resting systolic and diastolic blood pressure values (one prior to the 30 heart cycles, one during this time period, and another immediately after this time period) were taken using a digital blood pressure monitor (Bosu Medicus, Germany) and entered into the Physioflow to complete the calibration procedure. Heart rate and cardiac output were estimated continuously before (3 minutes) and after (1 minute) the task instructions were provided. Participants remained seated throughout these time periods. The difference between the final minute before and the minute after the task instructions (reactivity) was examined for all cardiovascular variables.

Task engagement. Changes in heart rate and cardiac pre-ejection period reflect the degree to which an individual is actively engaged in the task, with greater increases in heart rate and greater decreases in cardiac pre-ejection period indicating greater task engagement (Seery, 2011). According to the biopsychosocial model of challenge and threat, task engagement is required for challenge and threat evaluations to emerge. Cardiac pre-ejection period could not be estimated by the Physioflow and so heart rate alone was used to assess task engagement in the present study (as Derks, Scheepers, Van Laar, & Ellemers, 2011).

Challenge and threat index. Cardiac output and total peripheral resistance are cardiovascular indices that differentiate challenge and threat evaluations; with higher cardiac output and lower total peripheral resistance more reflective of a challenge evaluation (Seery, 2011). Cardiac output was estimated directly by the Physioflow whilst total peripheral resistance was calculated using the formula: [mean arterial pressure x 80 / cardiac output] (Sherwood, Allen, Fahrenberg, Kelsey, Lovallo, & Van Dooren, 1990). Mean arterial pressure was calculated using the formula: [(2 x diastolic blood pressure) + systolic blood pressure / 3] (Cywinski, 1980). In order to determine an individual's cardiovascular response an index was created by converting each participant's cardiac output and total peripheral resistance change scores into standardized *z*-scores and summing them. Total peripheral resistance was assigned a weight of -1 and cardiac output a weight of +1, such that a larger value corresponded with greater challenge (as Seery, Weisbuch, & Blascovich, 2009).

The Motor Task and Performance Measures

The basic laparoscopic surgery task was performed on a 3-Dmed (Franklin, OH) standard minimally invasive training system (MITS) with a joystick SimScope (a manoeuvrable webcam). The scene from within the training box is viewed, via the webcam, on a monitor positioned on top of the box (see Figure 1). An elongated surgical instrument passes through a port on the front of the box to enable the participant to manoeuvre objects within the box. Participants completed a ball pick and drop task, in which they had to use a single instrument (with the dominant hand) to move 6 foam balls (diameter; 5 mm) placed on stems of different heights, into a cup (Figure 1). The balls had to be grasped from their stems and placed into the cup individually and in a numbered sequence. Participants were asked to complete the task as quickly and as accurately (i.e., no dropped balls) as possible. Performance in the procedural task was assessed in terms of task completion time (as Wilson et al., 2011; Vine et al. 2012b). Participants were required to perform this task in a Baseline test; in repeated training trials; and in post-training Retention and Pressure tests (see Procedure below and Figure 2).

Figure 1 near here

Gaze Measures

Gaze was measured using an Applied Science Laboratories (ASL; Bedford, MA, USA) Mobile Eye Tracker. This lightweight system utilizes two features; the pupil and corneal reflection (determined by the reflection of an infrared light source from the surface of the cornea) to calculate point of gaze (at 30 Hz) relative to eye and scene cameras mounted on a pair of spectacles. A circular cursor, representing 1° of visual angle with a 4.5 mm lens, indicating the location of gaze in a video image of the scene (spatial accuracy of ± 0.5° visual angle; 0.1° precision), was viewed by the research assistant in real time on a laptop screen (Lenovo R500 ThinkPad) installed with *Eyevision* (ASL) recording software. Participants were connected to the laptop via a fire-wire cable and the researcher and laptop were located behind the participant to minimize distractions. The video data was recorded for subsequent offline analysis (as Moore et al., 2012).

Target locking. A measure of target locking was computed by subtracting the percentage of time spent fixating the tool from the time spent fixating on the target ball (throughout a trial). Therefore, a more positive score reflects more time spent target locking, whilst a more negative score reflects more time spent fixating the tools than the targets. A score of zero reflects equal time spent fixating the tools and targets (i.e., an equal switching strategy). A fixation was defined as a gaze maintained on a single location within 1° of visual angle for a minimum of 100 ms (≥ 3 frames of video; Wilson et al., 2011; Vine et al., 2012b). Fixations to “other” areas of the screen were ignored for the purpose of this analysis. These measures were derived from the video data using Quiet Eye Solutions software (www.QuietEyeSolutions.com). This software allows for the location and duration of fixations to be determined in a frame-by-frame manner.

Procedure

The procedure followed for the study is shown in Figure 2 and is elaborated below.

Baseline test. Participants were first fitted with the physiological recording equipment and ASL Mobile Eye Tracker. Subsequently, 3 minutes of cardiovascular data were recorded whilst participants sat still and quietly. Next, participants received standardized instructions relating to the Baseline test. These instructions outlined the specific details of the task and informed participants that they should complete the task as quickly and accurately as possible. This was followed by a 1 minute period during which cardiovascular data was recorded. Participants then reported their evaluated demands and resources. The participants were then asked to complete 1 trial of the laparoscopic pick-and-drop task (see measures section for a description) while performance and gaze data were recorded continuously.

Training. In the training phase, participants performed 50 training trials, divided by rest periods into 10 blocks of 5 trials of the same pick-and-drop task (a total of 300 ball ‘grasp and drop’ attempts). This phase of the experiment was designed to enable participants to reach a relative level of proficiency in the task. Previous research has shown that after 50 training trials novices reach a plateau in performance (Vine et al., 2012b). No instructions were provided during these trials.

Retention Test. After a short rest participants provided 3 minutes of cardiovascular data whilst sitting still and quietly. Participants then received standardized instructions relating to the Retention test - a repeat of the Baseline test that was designed to assess learning. This was followed by a 1 minute period during which cardiovascular data was recorded. Participants then reported their evaluated demands and resources and completed the MRF-3. The participants were then asked to complete 1 trial of the pick-and-drop task, while performance and gaze data were recorded continuously.

Pressure Test. After another short rest participants provided 3 minutes of cardiovascular data whilst sitting still and quietly. Participants then received standardized instructions relating to the Pressure test before a further 1 minute of cardiovascular data was recorded. Pressure was manipulated through the delivery of specific task instructions using several techniques that have been successfully adopted in a number of experimental studies (e.g., Vine & Wilson, 2011). First, a competition was set-up whereby participants were informed that the best performing individual would receive a £50 cash reward. Second, participants were told that their performance would be compared with others taking part and may be used as part of a presentation to their fellow students. Finally, non-contingent feedback was given to participants; informing them that their performance in the previous trial (Retention test) placed them in the bottom 30% when compared to those who had already taken part. They were instructed to try and improve upon their performance otherwise their data would be of no use for the study. Subsequently, participants reported their evaluated demands and resources and completed the MRF-3 before performing the task. Performance and gaze data were recorded continuously throughout the task. Upon completion of the Pressure test, participants were thanked and debriefed.

*****Figure 2 near here*****

Statistical Analysis

Baseline test. Task engagement was assessed at Baseline using a dependent *t*-test on the heart rate reactivity data to establish that in the sample as a whole, heart rate increased significantly after the task instructions were provided (i.e., heart rate reactivity greater than zero; as Seery et al., 2009)[2]. Regression analyses were performed to examine the extent to which challenge and threat evaluations (DRES) predicted (1) cardiovascular response (challenge and threat index), (2) performance (completion time), and (3) attentional control (target locking)[3]. DRES was entered as the independent variable and challenge and threat index, completion time, and target locking were entered separately as dependent variables[4]. Mediation analyses (using the PROCESS SPSS custom dialog, Hayes, 2013) were performed to test if the effect of DRES on completion time was mediated by target locking or challenge and threat index.

Pressure test. The effectiveness of the pressure manipulation was assessed using a dependent *t*-test on the MRF-3 data, in-order to establish if anxiety was significantly higher in the pressure test than the Retention test. Task engagement in the Pressure test was also assessed using a dependent *t*-test on the heart rate reactivity data[2]. Hierarchical regression analyses were performed to examine the extent to which demand resource evaluations (DRES) predicted challenge and threat index, target locking, and completion time, above and beyond the scores achieved at Retention (i.e. after training)[3.] Challenge and threat index, completion time, and target locking were entered separately as dependent variables, the level of the dependent variable at retention was entered at step one and DRES was entered as an independent variable at step two[4]. Mediation analyses (using the PROCESS SPSS custom dialog, Hayes, 2013) were performed to test if the effect of DRES on completion time was mediated by target locking or challenge and threat index.

Results

Table 1 presents the mean scores, standard deviations, and inter-correlations of all variables in the Baseline, Retention and Pressure tests.

*****Table 1 near here*****

Baseline test

Task engagement. The dependent *t*-test on the heart rate reactivity data revealed that in the sample as a whole, heart rate increased significantly from a mean of 76.53 (SD = 14.08) to 87.32 (SD = 14.36) after the instructions were provided, $t(51) = -12.86$, $p < .001$, $d = -3.64$. This significant increase confirms task engagement, permitting further examination of the relationship between variables of interest.

Task performance. Regression analysis revealed that DRES significantly predicted completion time ($R^2 = .11$)**.** Evaluating the task as more of a challenge as opposed to a threat was associated with better performance (i.e., faster completion times; see Table 2).

Challenge and threat index. Regression analysis revealed that DRES significantly predicted the challenge and threat index ($R^2 = .10$). Evaluating the task as more of a challenge as opposed to a threat was associated with a differential cardiovascular response (i.e., relatively higher cardiac output and relatively lower total peripheral resistance; see Table 2).

Target locking. Regression analysis revealed that DRES significantly predicted target locking ($R^2 = .08$)**.** Evaluating the task as more of a challenge as opposed to a threat was associated with superior attentional control (i.e., a higher target locking score; see Table 2).

Mediation analysis. Mediation analyses were performed to test if the effect of DRES on completion time was mediated by target locking or challenge and threat index. Based on a 10,000 sampling rate, the results from bootstrapping revealed no significant indirect effects for target locking (95% CI = -6.77 to 0.01) or challenge and threat index (95% CI = -8.98 to 0.17) at Baseline.

Pressure test

Cognitive anxiety. The dependent *t*-test on the cognitive anxiety (MRF-3) data revealed a significant difference between the Retention and Pressure tests, $t(51) = 6.00$, $p < .001$, $d = 1.68$, with participants experiencing greater cognitive anxiety during the Pressure test (mean, 5.40, $SD = 2.61$) than the Retention test (mean, 3.56, $SD = 2.05$), thus confirming the effectiveness of the pressure manipulation.

Task engagement. The dependent *t*-test on the heart rate reactivity data revealed that heart rate increased significantly from a mean of 74.34 ($SD = 16.85$) to 85.58 ($SD = 13.04$) after the instructions were provided, $t(51) = -5.81$, $p < .001$, $d = 2.83$, again confirming task engagement.

Task performance. Regression analysis revealed that DRES significantly predicted task performance ($\Delta R^2 = .24$) over and above the effects of task performance in the Retention test ($R^2 = .13$). While 13% of the variance in performance during the Pressure test was explained by performance in the Retention test, an additional 24% of variance was explained by DRES. Evaluating the task as more of a challenge as opposed to a threat was associated with superior performance under pressure (i.e., faster completion times; see Table 2).

Challenge and threat index. Regression analysis revealed that DRES did not significantly predict the challenge and threat index (ΔR^2 = .01), over and above the effects of the challenge and threat index in the Retention test (R^2 = .01; see Table 2).

Target locking. Regression analysis revealed that DRES significantly predicted target locking (ΔR^2 = .13), over and above the effects of target locking in the retention test (R^2 = .21). While 21% of the variance in target locking during the pressure test was explained by the target locking score in the retention test, an additional 13% of variance was explained by DRES. Evaluating the task as more of a challenge as opposed to a threat was associated with superior attentional control under pressure (i.e., a higher target locking score; see Table 2).

Mediation analysis. Mediation analyses performed to test if the effect of DRES on completion time was mediated by target locking or challenge and threat index. Based on a 10,000 sampling rate, the results from bootstrapping revealed no significant indirect effects for target locking (95% CI = -0.82 to 0.36) or challenge and threat index (95% CI = -0.74 to 0.04) at Pressure.

Table 2 near here

Discussion

Evaluating a stressful task as a challenge, compared to a threat, has been shown to lead to superior future performance and better immediate cognitive task performance (Blascovich et al., 2004; Turner et al., 2012). However, to date only one study has examined the direct and acute effects of challenge and threat evaluations on the performance of a novel perceptual-motor task (Moore et al., 2012). Furthermore, research has yet to examine the effect of these evaluations on the performance of a trained motor task under pressurized conditions, and investigate the attentional mechanisms through which such evaluations might impact upon performance. Thus, the purpose of the present study was to examine the effect of challenge and threat evaluations upon the performance of a perceptual motor task (laparoscopic surgery), for which optimal visual attention control has been identified. The relationships between demand and resource evaluations (DRES) and both performance and visual attention were examined at two time points; prior to a period of training when the task was novel (Baseline test) and under pressurized conditions following a period of training when individuals were proficient at the task (Pressure test).

Novel Motor Task Performance (Baseline test)

In accordance with previous research, evaluating the task as more of a challenge as opposed to a threat was associated with a differential cardiovascular response. Regression analysis suggested that participants evaluating that they possessed sufficient resources to cope with the demands of the task had a lower challenge and threat index. Specifically, following Baseline task instructions, evaluating the task as more of a challenge led to relatively higher cardiac output and lower total peripheral resistance (Seery, 2011). These findings corroborate the subjective evaluation of demand and resource evaluations made by the participants, and offer support for the biopsychosocial model of challenge and threat and its predictions.

As hypothesized, the regression analysis on the performance data revealed that evaluating the task as more of a challenge (compared to threat) led to the task being completed more quickly. The superior performance associated with evaluating the task as more of a challenge was accompanied by more effective visual attentional control, as indexed by a higher target locking score. This visual attentional strategy has been previously shown to underpin expertise in a similar surgical task (Wilson et al., 2011) and supports models of visuomotor control that stress the importance of directing visual attention to locations relevant to the task at hand (Land, 2009). The results therefore corroborate those of Moore et al. (2012) in golf putting, and offer initial support for the generalizability of this finding to different perceptual motor tasks. However, it is also one of the aims of this study to examine whether this finding extends to individuals who are performing a learned motor task under pressurized conditions. Arguably, this is a more important question in applied environments, where pressure (anxiety) might degrade the performance and attentional control of even experienced individuals. Indeed, in environments such as surgery there has been a tendency to ignore or deny the impact of pressure and stress on performance (Arora, Sevdalis, Nestel, Woloshynowych, Darzi, & Kneebone, 2010), so such research is necessary to inform best practice for curriculum development and training (McGrath, Moore, Wilson, Freeman, & Vine, 2011).

Proficient Motor Task Performance (Pressure test)

Evaluating the task as more of a challenge (as opposed to a threat) did not lead to a differential cardiovascular response in the pressure test (cf. Baseline test). Specifically, an increase in DRES was not associated with an increased challenge and threat index. Previous studies have also reported mixed findings in relation to associations between self-report and cardiovascular measures when testing the biopsychosocial model of challenge and threat (e.g., Fairclough & Spiridon, 2012). There are several possible explanations for this null finding. First, previous research has shown that cardiovascular reactivity is attenuated following repeated exposure to a particular task (Kelsey, Blascovich, Tomaka, Leitten, Schneider, & Wiens, 1999). Thus, given that participants had performed 52 trials of the task before the Pressure test, their cardiovascular response may have been dampened, reducing the association between their evaluation (DRES) and cardiovascular response (challenge and threat index). Second, cardiovascular responses to challenge and threat evaluations are typically measured *during* task performance (see Seery, 2011). Cardiovascular responses were assessed *prior* to the task in the current study, at which time pressure may not have been at its highest and cardiovascular responses attenuated[5]. However, had cardiovascular measures been assessed during the motor task (when pressure was arguably at its highest), artefacts that originate from the increased physical movement (e.g., standing and moving arms) may have confounded cardiac reactivity measures (Blascovich & Mendes, 2000).

Despite the lack of association between DRES and challenge and threat index, evaluating the Pressure test as more of a challenge led to the task being completed more quickly. The better performance was again accompanied by more effective visual attentional control, as indexed by a higher target locking score. The pressure test results therefore extend the work of Moore et al. (2012) and demonstrate that challenge and threat evaluations can also influence the attentional processes and performance of trained individuals completing a motor task under heightened pressure. Previous research has shown that increased pressure acts to disrupt visual attentional control and motor performance in a similar surgical task (Wilson et al., 2011), yet the findings of the current study suggest that evaluating a situation as a challenge (despite still experiencing high levels of anxiety) may protect individuals from such disruption.

Theoretical and Applied Implications

The findings of the present study have some important theoretical and applied implications. First, the findings suggest that the biopsychosocial model of challenge and threat (Blascovich, 2008) may provide a useful framework by which individual differences in motor skill performance under pressure can be examined and better understood. The findings add to research supporting the biopsychosocial model of challenge and threat by showing that challenge and threat evaluations predict performance in pressurized environments when accurate motor task performance is essential. However, the results from the current study did not shed any further light on the role of cardiovascular response in this relationship. Specifically, whereas DRES significantly predicted challenge and threat index, challenge and threat index did not mediate the relationship between DRES and performance. As a result, cardiovascular changes that result from subjective demand and resource evaluations of a motor task do not appear to explain performance variability in that task.

Second, the positive relationship between DRES and target locking may support the predictions of attentional control theory (Eysenck et al., 2007), as threat evaluations were linked to less effective attentional control. According to attentional control theory, heightened threat (anxiety) causes an increase in influence of a stimulus driven (bottom up) attentional control system, at the expense of a goal directed (top down) system. As a result, the association between increased threat evaluations (DRES) and decreased target locking (more switching) may be reflective of the increase influence of the stimulus driven attentional control system. However, despite the positive correlation between target locking and completion time (see table 1) which has been shown in previous research (Vine et al., 2012b; Wilson et al., 2011), target locking did not mediate the relationship between DRES and completion time. In future, researchers should attempt to explore other potential mediators that might explain the relationship between subjective evaluations of challenge and threat and performance in motor tasks. Such mediators may potentially provide a bridge between the tenets of the theories examined in the current study. For example, the application of effort has been implicated in both mediating the influence of anxiety on effective attentional control (see Nieuwenhuys & Oudejans, 2012) and as an antecedent of demand and resource evaluations in the biopsychosocial model of challenge and threat (Blascovich, 2008).

There are also clear implications for how individuals should be trained to deal with pressure and for the kind of instructions or guidelines that individuals are provided with before performing under pressure. The findings support interventions designed to encourage individuals to evaluate highly demanding and pressurized tasks more adaptively, as a challenge rather than a threat (McGrath et al., 2011). Importantly, the present study demonstrates that these beneficial effects could be experienced by individuals performing novel motor tasks for the first time (e.g., a child learning a new skill) as well as individuals performing tasks which have been trained (e.g., an experienced surgeon). The biopsychosocial model of challenge and threat suggests that a challenge evaluation may be fostered by reducing the evaluated demands of the task or by increasing the actual or evaluated resources of the individual. A range of factors could be targeted to alter demand and resource evaluations including, but not limited to, familiarity, uncertainty, difficulty, danger, attitudes, and the presence of others (Seery, 2011). Alternatively, interventions that have been shown to help performers maintain effective goal directed attentional control when performing motor skills (e.g., gaze training; see Vine & Wilson, 2011; Vine et al., 2012a) might be useful in helping individuals who adopt a threat state to continue to perform motor skills effectively. The benefits of both of the above approaches may be of particular relevance to safety critical industries (e.g., surgery, aviation, emergency medicine) where motor skills must be performed in highly pressurized environments (see McGrath et al., 2011).

Limitations and Future Directions

Despite the encouraging findings the present study is not without its limitations. First, as the current study did not manipulate demand and resource evaluations and thus challenge and threat states, it is difficult to make strong causal claims. Therefore, we encourage researchers to adopt study designs that incorporate careful experimental manipulations (as Moore et al., 2012).

Second, several authors have noted the dynamic nature of demand and resource evaluations and how these evaluations tend to fluctuate over time (Blascovich, 2008; Jones et al., 2009; Quigley, Feldman Barrett, & Weinstein, 2002). From an applied perspective, there are implications for the potential use of such markers in the process of selection or training (McGrath et al., 2011). Clearly, challenge and threat evaluations are dynamic and would be inappropriate for determining individuals who might best cope with pressure[6]. Thus, it may be interesting to examine how initial evaluations change during a training period as individuals became more familiar and proficient with the task.

Third, the antecedents of challenge and threat states were not assessed in this study but could be examined in future research. A range of situational factors have been proposed to influence the demand/resource evaluation process including psychological and physical danger, familiarity, uncertainty, required effort, skills, knowledge and abilities, and the availability of external support (Blascovich, 2008).

Finally, a potential limitation of the current study is the pressure manipulation that was used. Offering a financial incentive for participants may have acted to frame the task in terms of potential for gain, rather than potential for loss, which may have influenced the participants challenge/threat evaluations and subsequent performance (see Seery et al., 2009). Similarly a number of dispositional traits such as trait anxiety (Eysenck et al., 2007) or motivational orientation (Worthy, Markman, & Maddox, 2009) may also have an effect on demand and resource evaluations, and future research should examine how these traits interact with pressure manipulations and incentives to influence challenge and threat evaluations and performance.

Conclusion

To conclude, the results demonstrate that challenge and threat evaluations can have a direct effect on the performance of both novel motor tasks and trained motor tasks under elevated pressure. Evaluating a task as more of a challenge (as opposed to a threat) was associated with superior visual attentional control and performance. Thus, the findings imply that challenge and threat evaluations impact both motor task performance and the attentional processes underpinning the motor task. However, more research is required to understand precisely *how* these evaluations influence motor task performance and if these are the same for both novel tasks and tasks with which individuals have experience. Finally, the results infer that perceptual motor performance could be facilitated by encouraging individuals to evaluate tasks as a challenge, or to train attention to remain robust, even when anxious.

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Table 1: Correlations between study variables.

	Mean	*SD*	1	2	3	4	5	6	7	8	9	10
1. [B] DRES	-0.87	1.09										
2. [B] Completion time	66.13	32.59	-0.34*									
3. [B] Challenge and threat index	0.00	1.05	0.32*	-0.37**								
4. [B] Target locking	-3.07	47.10	0.28*	-0.30*	-0.00							
5. [R] Completion time	32.33	10.74	-0.20	0.24	-0.10	-0.04						
6. [R] Challenge and threat index	0.00	1.27	-0.10	0.16	-0.06	-0.20	0.32*					
7. [R] Target locking	50.21	41.00	-0.11	-0.21	-0.06	0.34*	0.05	-0.08				
8. [P] DRES	-0.13	1.83	0.25	-0.34*	-0.04	0.35*	-0.37**	-0.08	0.17			
9. [P] Completion time	30.73	10.29	0.10	0.22	0.19	-0.38**	0.36**	0.28*	-0.16	-0.59***		
10. [P] Challenge and threat index	0.00	1.00	0.12	-0.07	0.17	0.15	0.06	-0.09	0.11	-0.11	0.20	
11. [P] Target locking	34.29	41.56	0.20*	-0.29*	0.10	0.63***	-0.04	-0.23	0.46**	0.43**	- 0.30*	0.09

*[B] = Baseline test; [R] = Retention test; [P] = Pressure test. * = P < 0.05; ** = P < 0.01; ***P < 0.001*

Table 2: Results from the linear regression analysis performed on the Baseline test data, and the hierarchical regression analysis performed on the Retention and Pressure test data.

Dependent variable	Step (where relevant)	Independent variable	B	SE B	*t*
[B] Completion time		[B] DRES	-10.14	4.00	-2.54*
[B] Challenge and threat index		[B] DRES	0.31	0.13	2.40*
[B] Target locking		[B] DRES	11.93	5.93	2.01*
[P] Completion time	1	[P] DRES	-2.96	0.69	-4.30***
	2	[R] Completion time	0.16	0.12	1.38
[P] Challenge and threat index	1	[P] DRES	-0.06	0.08	-0.81
	2	[R] Challenge and threat index	-0.08	0.11	-0.70
[P] Target locking	1	[P] DRES	8.25	2.80	3.00**
	2	[R] Target locking	0.40	0.13	3.20**

*[B] = Baseline test; [R] = Retention test; [P] = Pressure test. * = $P < 0.05$; ** = $P < 0.01$; ***$P < 0.001$*

Footnote 1: If resources are rated as 1, then an increase in demands from 1 to 6 would produce a change in the ratio from 1 to 6. However, if a person rates resources as 6, then an increase in demand from 1 to 6 would produce a change in the ratio from 0.17 to 1. The authors would like to thank an anonymous reviewer for this observation.

Footnote 2: For the Baseline and Pressure tests heart rate reactivity data a total of ten univariate outliers (values more than 3.3 standard deviation units from the grand mean; Tabachnick & Fidell, 1996) from three participants were winsorized by changing the deviant raw score to a value 1% larger or smaller than the next most extreme score (as Shimizu, Seery, Weisbuch, & Lupien, 2011).

Footnote 3: To control for potentially confounding effect of age it was entered as a first step in all regression analyses. As this did not significantly influence the outcome of the results we have not reported these findings. The authors would like to thank an anonymous reviewer for this suggestion.

Footnote 4: Difference scores suffer from a number of methodological problems (see Edwards, 2001 for a review). Specifically, the difference score used in this study (DRES) implies a specific relationship between the component variables (demands and resources) and the outcome variable (completion time, challenge and threat index, or target locking). In order to test this assumption, polynomial regression analyses were performed on the completion time data at both the Baseline and Pressure test (see Edwards, 1994). Findings were supportive of the use of difference scores, and therefore DRES was entered as the independent variable in all regression analyses.

Footnote 5: The authors would like to thank an anonymous reviewer for this comment.

Footnote 6: DRES at Baseline did not significantly predict performance at Pressure ($R^2 = .01$, $\beta = .1$, $p = .50$). This suggests that demand and resource evaluations are susceptible to change over time (see discussion).

Figures and captions:

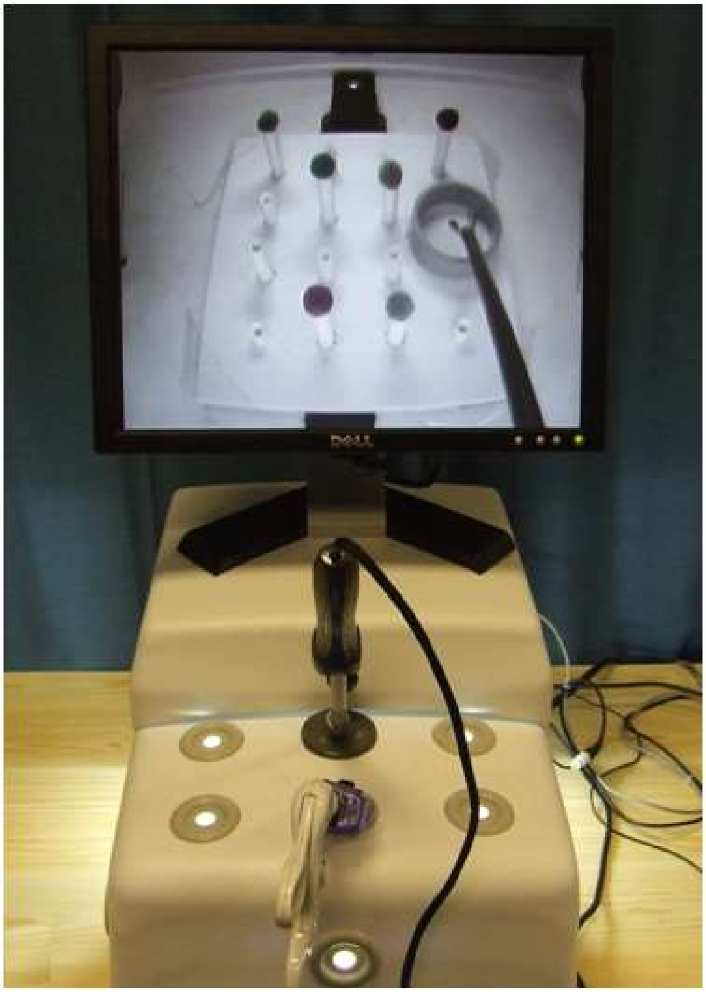

Figure 1: The 3-Dmed box trainer displaying the laparoscopic ball pick and drop task.

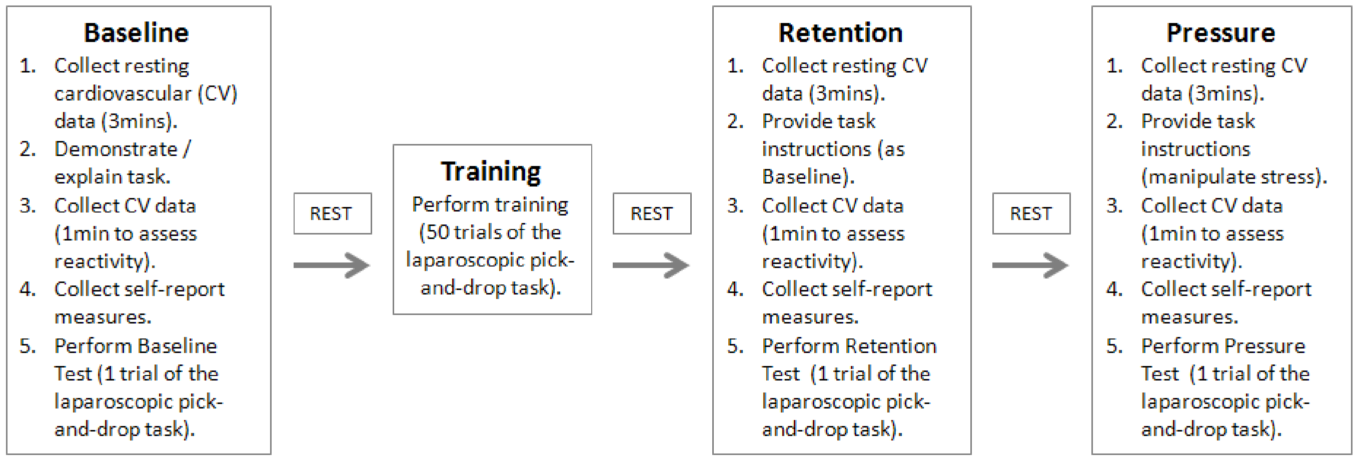

Figure 2: A schematic representing the testing protocol used, consisting of a Baseline Test (to assess novice performance), a Training period (to train participants to proficiency), a Retention Test (to control for changes as a result of training), and a Pressure Test (to assess responses to increased pressure).